Papers in Laboratory Phonology V
Acquisition and the Lexicon

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Introduction

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This volume is the fifth in the series *Papers in Laboratory Phonology*, representing the results of the fifth Conference on Laboratory Phonology, which was hosted by Northwestern University in July 1996. A decade after the inauguration of the series, the formula so brilliantly conceived by Beckman and Kingston in 1987 has blossomed to a vigorous maturity. The series now represents a premier forum for experimental work on the sound structure of language. We have been preceded and will be succeeded by many others in continuing what is now an established tradition. The main credit for this success belongs to the many researchers who have contributed their work to the series, and to the commentators and members of the audience who created from the very start an atmosphere of genuine and constructive intellectual interaction.

It is the privilege of the editors of each volume to identify themes for the purpose of focussing discussion. The themes we have selected are Language Acquisition and the Lexicon. Our purpose in selecting these themes is to further what we would see as a signal development in laboratory phonology over the last decade. In the past, phonetics has sometimes figured as a sort of handmaiden to phonological theory, taking the entities suggested by phonologists as given and providing real-world referents for these entities through the use of measurements and perceptual tests. Work on the phonology-phonetics interface published in the Laboratory Phonology series has turned the tables, by using phonetic data to shape as well as to execute the phonological theory. The first two areas of progress were in deriving possible phonemic inventories from the characteristics of the phonetic system (Kingston 1990, Ohala 1992, Hajek & Maeda this volume)—an enterprise which goes back to the original works on the acoustic theory of speech production (Fant 1960)—and using phonetic implementation as a boundary condition on phonology. Models of phonetic implementation (such as Coleman 1994, Browman and Goldstein 1992, Hertz 1990) constrained the

phonological model by clarifying its responsibilities and by demanding that it provide all the information that the phonetic implementation requires. In particular, work on phonetic implementation validated and clarified the theory of hierarchical structures in phonology by delineating the ramifications of such structures in the phonetic outcomes (see Pierrehumbert & Talkin, Silverman & Pierrehumbert, previous volumes; and Byrd et al., Beckman & Edwards, this volume).

Increasingly, however, laboratory phonology is going beyond these two initial inroads into phonological theory. First, laboratory phonologists are looking at more and more types of experimental results, not just results in linguistic phonetics. Secondly, they have begun to explore the hypothesis that syntagmatic relations (and not just phonological inventories) are grounded in articulatory, perceptual, and cognitive capabilities. As a result, the research effort is now positioned to take on the central questions of generative phonology, namely 'What is a possible word?' and 'What human capabilities enable us to acquire productive use of language from the finite evidence available to us?' These questions are recognized as closely interconnected, as the possible words of any language are ones which conform to the implicit phonological knowledge which is acquired. We were extremely gratified by the response to the themes we proposed and we were able to include only a small fraction of the outstanding submissions we received. We would particularly like to thank the researchers who recognized and took up the opportunity to explore the relationship of lexical representation to acquisition, thereby binding the two special themes of the conference into a single whole.

A major purpose of the laboratory phonology series has been to foster interaction amongst people working on speech from different perspectives. Underlying this diversity, we see certain commonalities which have provided a basis for intellectual progress. We would like to mention some of these commonalities which jump to our attention in the present group of papers. First, we are impressed by the open-minded and opportunistic approach to empirical data. The shared goal of all the papers is to understand what special characteristics of the human mind and body are responsible for the linguistic virtuosity of human beings. In the interests of achieving this goal, the various authors are willing to take up all and any data which promise to be revealing. There is no a priori distinction between linguistic data and external data, or between competence data and performance data. Many of the papers use acoustic and articulatory measures; others use perceptual data (Newman et al., Lotto et al.), patterns of attention by babies (Goodman & Jusczyk, Werker & Stager), linguistic typology (Steriade, Hajek & Maeda); patterns of historical change (Bybee, Hajek & Maeda), speech errors (Frisch), well-formedness judgments and performance in blending (Treiman et al.), interference in second language acquisition (Kondo), measures of brain activity (Coleman). Several authors undertake an integrated

account of more than one type of data. This approach to data is the hallmark of a thriving empirical science.

A second observation is that the papers in this volume have a much more substantial reliance on statistics than the typical collection of phonology papers. At one level, this fact is a consequence of the empiricism mentioned in the last paragraph. Most raw data about language exhibit statistical variability, however much some theoreticians and formalists may downplay this fact. Any linguistic scientist who responsibly confronts a data set at once begins to raise questions about the statistical reliability of the patterns which may appear to be present. A long and honorable tradition of application of statistics by psychologists and by experimental phoneticians underlies the very idiom of the experimental results presented here. However, many papers in the present volume go beyond this workaday use of statistics in data analysis and inquire into the cognitive status of the observed statistical variability. These papers all show that statistical variability is not a quantitative fog obscuring a deeper and more hard-edged reality. Instead, implicit knowledge of language is by its very nature statistical. This point is made by Bybee in connection with leniting historical changes; by Treiman et al. in relation to syllable structure; by Beckman & Edwards in their experimental study of acquisition; by Newman et al. in the exploration of phoneme frequency and lexical neighborhood effects in perception; and by Frisch's development of the relationship between similarity and frequency. As Dell points out in his final summary, this consensus about the role of frequency marks a major departure from classical generative phonology and suggests an entirely different type of architecture for the implicit knowledge which generative phonology seeks to model.

Third, we note the ascension of non-derivational approaches to phonological well-formedness. Papers in this volume draw on a number of phonological frameworks. Gussenhoven, Cole, and Steriade draw on Optimality Theory, as laid out in Prince and Smolensky (1993). Papers in previous volumes draw on principles of Declarative Phonology. Dell argues that the effects of frequency laid out in his session can only be understood in a connectionist approach, with Coleman and Lotto endorsing this view. Conspicuously missing—not only from the volume, but also from the much larger set of original submissions—are papers which presuppose that lexical items are derived from abstract underlying representations by transformational rules applying in some order, as proposed in Chomsky & Halle (1968).

In what follows, we'd like to provide our own perspective about where laboratory phonology has come and where it can go with its opportunistic methodology and its nonderivational stochastic architectures. What can we now conclude about the relationship between physical nature of speech and the central questions of phonology proper? As Kingston & Beckman already point out in the introduction to the first volume in the series, a relentless tide of evidence and

scientific consensus has built up against Trubetzkoy's declaration that 'Phonetics is to phonology as numismatics is to economics'. That is, phonology is not a purely formal system whose structure and behavior is divorced from its substantive instantiation. Rather, phonology reflects phonetic substance at all levels of description. It is built on the dimensions of contrast which are made available by articulation and psychoacoustics. The linguistically available combinations of values along these dimensions are constrained by their actual physical interactions. The natural classes of phonological elements, as revealed by allophony, phonotactics, and morphophonemic alternations, are all heavily shaped by their phonetic similarity.

The single breakthrough which contributed most to these conclusions was the acoustic theory of speech production, which forty years ago first made it possible to relate critical aspects of the articulatory configuration to perceptually salient aspects of the acoustic outcome. The approach exemplified by Fant (1960) has been overwhelmingly validated by the advances in articulatory, acoustic, and aerodynamic modeling which have taken place since then; as far as segmental inventories go, Trubetzkoy's dualist stance is no longer in the discussion. The papers in this collection extend and deepen our understanding of the contribution of the physical basis of speech to its cognitive architecture.

Consider the fact that the dimensions of contrast made available by the physical system are demonstrably non-orthogonal. For example, although oral constriction and laryngeal constriction are separately controlled, the fricatives show that they are not functionally orthogonal. Fricatives are characterized by turbulence at a constriction, and to achieve this turbulence, high airflow is required. This means that they are ordinarily produced with a spread glottis (Shadle 1990). Voiced fricatives are unstable towards voiceless fricatives on the one hand and voiced approximants on the other: constricted glottis fricatives are impossible. If the dimension of oral constriction were orthogonal to that of glottal opening, all combinations of degree on both parameters would be equally functional, but this is obviously not the case. Insofar as phonological features are contentful, they are not orthogonal. Feature geometry represents an attempt to give recognition to this idea, but the example cited shows that acoustic and aerodynamic dependencies in the vocal tract go well-beyond the purely articulatory dependencies recognized in that framework (Clements 1985, Ohala 1990).

Now any deviation from orthogonality implies redundancy. This point was well-recognized by early research in generative phonology (see for example, Cherry, Halle & Jakobson 1953). An inventory of, say, 40 segments requires between 5 and 6 bits of information for its articulation; SPE incorporates a feature system in which the phonetically transparent features supply a potential 35 bits of information—sufficient to discriminate, if orthogonal, 2^{35} (over 34 billion) segments. This vast number already arises under a theory in which phonetic dimensions are reduced to two polar values. If we consider the phonetic

dimensions in full detail, it is obvious that phonology is even less space-filling than this. Hence lexical representations (conceived as made up of phonetically contentful elements) are, necessarily, massively redundant. This conclusion about the lexicon lies on a direct trajectory from the large body of work on the phonetic basis of phonological inventories.

Cherry et al. argued that massively redundant data structures presented problems of memory and processing. Their response was to propose that all but a few values of features appear as blanks in lexical representations and are filled in by a sequence of derivational rules. This proposal was adopted in various manifestations throughout the history of generative phonology under the name of underspecification theory (see Steriade 1995 for overview). Several papers in this book (Newman et al., Bybee, Frisch, Steriade, Dell) demonstrate that this position is untenable. Newman et al. provide evidence that the phoneme /t/ (which is unspecified for both place and voicing according to standard versions of underspecification theory, see Paradis & Prunet 1991) is more robust than other phonemes against lexical neighborhood effects in perception. They convincingly attribute this behavior to its high frequency. However, as pointed out by Dell, blanks in a phonological representation should render the representation vulnerable rather than robust. In general, blanks do not support frequencies since they provide nothing to be counted. Bybee, Frisch, and Steriade also provide different kinds of evidence that the most abstract lexical representations still include a good deal of redundant detail, and hence are not minimized in the way underspecification theory proposes. Steriade, for example, argues for phonetic level paradigm uniformity effects, an instance of lexical structuring due to phonetic analogy.

We can locate this discussion in a broader context by considering what function redundancy serves and how it arises. As observed by Hockett, redundancy is functional because it is the only known antidote to noise. Natural language can employ only those gestures which are perceptually discriminable, and to be robust, only those that are discriminable in noise. All physically realized signaling systems operate in noisy environments, and thus all incorporate the redundancy solution as an integral design characteristic. For speech, the sources of noise include ambient noise masking the signal during transmission, but also variability in articulation, and variability in perception. In addition, language is shared amongst the individuals of a culture and thus needs to be robust across variation amongst individuals. What then is noise? It is random perturbation of the signal; it has an essentially stochastic nature. From this fact, we can derive a theoretical nexus amongst redundancy, probability, and contrastiveness.

A group of papers in the present volume specifically explore contrastiveness as a shaping force in the acquisition of phonology. Lotto et al. relate the categorization of the vowel space to general processes of auditory categorization found in birds as well as in people. One interesting aspect of their data is a replication

of findings by Johnson, Flemming & Wright (1993) that extreme values of vowel formants may count as better than typical values (contra Kuhl, 1991). These findings provide support for Lindblom's claim that linguistic categories are driven by contrastiveness. Contra Lindblom, however, Lotto et al. show that this impetus does not specifically depend on communicative intent, but may also arise from other functionality (such as a food reward for the starlings in their experiments). Scobbie et al. present detailed data on children who appear to lack a phonological contrast found in the adult language. They show that these children may have grasped the existence of the contrast while being mistaken about the phonetic strategies used to implement it. Previous work on such 'covert contrasts' has reported mistakes in the degree, rather than the nature, of the phonetic attributes involved in the contrast. Werker & Stager address the apparent paradox posed by the crudeness of young children's initial phonological systems. Although babies are better than adults at perceiving subphonemic contrasts, toddlers initially display phonological systems which are less differentiated than the adult system. In these results, we see how far phonological organization is from phonetic perception; unlike early phonetic perception, phonological organization is driven by lexical contrast. When toddlers first 'discover' the lexical function of the phonetic signal, their cognitive organization is simpler than adults'. It becomes increasingly differentiated as they acquire more experience with the relationship of the phonetic signal to contrasts in the lexicon. As we see from Munhall et al.'s discussion, even the full-fledged adult phonology is not as finely differentiated as a fully detailed phonetic description. In the adult phonology, correlated dimensions tend to be bundled together so that a phonological description is distinctly more schematic than a phonetic one. This is precisely what allows the phonology to be as robust across the many sources of variation as it is.

The nexus amongst redundancy, probability and contrastiveness is also apparent in papers in the present volume which deal with syntagmatic structure. Robustness against noise is not merely a factor in shaping paradigmatic contrasts, it also shapes syntagmatic structures. Redundancy amongst elements in sequence makes it possible to recover from interruption noise. From this point of view, coarticulation is not an impediment to comprehension—a regrettable articulatory smearing of entities which would be well separated in a more ideal world. Instead, information in the speech signal which results from coarticulation could assist the listener in under conditions of intermittent noise. It thus not surprising that the nature and extent of coarticulation are subject to codification in individual languages, an issue explored in Kondo's study of second language acquisition. Implicit knowledge of coarticulation is also discussed by Coleman, and Munhall et al.

Statistical dependencies at a more abstract level of description would be functional for the same reason. Treiman et al. demonstrate that native speakers have

implicit knowledge of the statistical dependencies in the rime, as shown by well-formedness judgments and outcomes of a blending task. A closely related issue arises when considering the temporal course of attention. When people are paying attention, they can grasp more distinctions than when they are not paying attention, and thus inattention has some of the consequences of external noise. The contribution by Frisch provides evidence that the location of information in the phonological representations of words is matched to the time course of attention in lexical access. There is more information near the beginning of words, where attention is greatest. Goodman & Jusczyk compare the importance of syllable onsets to syllable rimes in the perceptions of 18 month olds, and find that the infants are more attentive to onsets.

Further results on positional contrastiveness may be found in contributions by Harrington et al., Byrd et al., and Edwards. With statistical dependence and phonetic coproduction being functional within phonological units, we expect to find statistical independence and phonetic separation across boundaries. Byrd et al. report detailed findings on the phonetic properties of phrase boundaries in Tamil. Harrington et al. examine the relation between paradigmatic and syntagmatic contrast, in the context of competing strategies for maximizing the acoustic realization of phonological distinctions. Edwards makes the very interesting observation that elaboration of the lexical inventories of small children may be bootstrapped from their practice with the complex articulatory requirements of multiword utterances. Their ability to learn individual words with two different syllable onsets appears to be born of the ability to make two word utterances, in which the onsets of the words would be in general independent.

Laboratory phonology is a healthy research community. In such a community, scientific results accumulate and give birth to theories. The results presented in this book have been achieved by many different methods, and they all point to a theory of phonology which is grounded both in articulatory and acoustic phonetics and in properties of the cognitive system. In this theory, lexical representations are highly redundant. Frequency is an engine of patterning. Lexical contrast interacts with phonetic capabilities to give rise to the abstract entities of phonology. Adult phonology emerges as the end result of an acquisition process in which perceptual acuity, articulatory practice, and lexical functionality all play a role.

We believe that the increase in the range of empirical issues under investigation, together with an increasing capacity of theoretical models to respond to the data, bodes well for a period of vibrant research development in the future. We look forward optimistically to the next decade of results from the laboratory phonology community.